

RESEARCH ARTICLE

The Effects of Different Training Backgrounds on $\dot{V}O_2$ Responses to All-Out and Supramaximal Constant-Velocity Running Bouts

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Abstract

To investigate the impact of different training backgrounds on pulmonary oxygen uptake ($\dot{V}O_2$) responses during all-out and supramaximal constant-velocity running exercises, nine sprinters (SPRs) and eight endurance runners (ENDs) performed an incremental test for maximal aerobic velocity (MAV) assessment and two supramaximal running exercises (1-min all-out test and constant-velocity exercise). The $\dot{V}O_2$ responses were continuously determined during the tests (K4^{b2}, Cosmed, Italy). A mono-exponential function was used to describe the $\dot{V}O_2$ onset kinetics during constant-velocity test at 110%MAV, while during 1-min all-out test the peak of $\dot{V}O_2$ ($\dot{V}O_{2peak}$), the time to achieve the $\dot{V}O_{2peak}$ ($t\dot{V}O_{2peak}$) and the $\dot{V}O_2$ decrease at last of the test was determined to characterize the $\dot{V}O_2$ response. During constant-velocity exercise, ENDs had a faster $\dot{V}O_2$ kinetics than SPRs (12.7 ± 3.0 vs. 19.3 ± 5.6 s; $p < 0.001$). During the 1-min all-out test, ENDs presented slower $t\dot{V}O_{2peak}$ than SPRs (40.6 ± 6.8 and 28.8 ± 6.4 s, respectively; $p = 0.002$) and had a similar $\dot{V}O_{2peak}$ relative to the $\dot{V}O_{2max}$ (88 ± 8 and $83 \pm 6\%$, respectively; $p = 0.157$). Finally, SPRs was the only group that presented a $\dot{V}O_2$ decrease in the last half of the test (-1.8 ± 2.3 and 3.5 ± 2.3 ml.kg⁻¹.min⁻¹, respectively; $p < 0.001$). In summary, SPRs have a faster $\dot{V}O_2$ response when maximum intensity is required and a high maximum intensity during all-out running exercise seems to lead to a higher decrease in $\dot{V}O_2$ in the last part of the exercise.

Introduction

Short and intense running exercise requires substantial contributions from both aerobic and anaerobic systems [1]. But, a high accumulation of metabolites derived from anaerobic metabolism can impair running performance [2]. Therefore, modifications in the oxygen uptake ($\dot{V}O_2$) response, affecting energy metabolism and the extent to which the intra-muscular milieu is perturbed, are useful for improving performance in this kind of exercise [3].

During moderate and heavy constant work-rate exercise, endurance athletes (ENDs) have faster pulmonary $\dot{V}O_2$ kinetics than sprinters (SPRs) [4–6], which increases the aerobic contribution from the onset of exercise. However, during competitive running events, speed varies throughout a race (specifically with higher start speeds) [7–9]; therefore, constant work-rate exercises do not represent a “real life” performance. Surprisingly, to our knowledge, no previous study has compared $\dot{V}O_2$ responses between ENDs and SPRs during long sprint running performances, though it seems to be one of the factors setting maximal performances in track running [10]. The short nature of performances around 1-min requires the subjects to maintain nearly maximum effort throughout the exercise [11], demanding that their anaerobic systems approach maximal rates of ATP resynthesis in the active muscles. This can lead to a potential speed-up in the $\dot{V}O_2$ response [9, 12] since for some models the changes per unit time in $\dot{V}O_2$ is proportional to the rate of phosphocreatine (PCr) breakdown in the active muscles per unit of change in time (i.e., the $\Delta[PCr]/\Delta t$ ratio) [13, 14]. While ENDs have shown faster $\dot{V}O_2$ kinetics for constant work-rate exercises [6, 15], SPRs might be more prone to speed-up the $\dot{V}O_2$ kinetics during all-out exercises than ENDs due to faster PCr breakdown [16, 17].

On the other hand, the higher anaerobic ATP turnover at the onset of all-out exercise in SPRs may also cause different impacts on the subsequent $\dot{V}O_2$ compared to the ENDs. Recent studies have shown that a fast start strategy leads to a decrease in $\dot{V}O_2$ toward the end of races [8, 9, 18] as a result of metabolic perturbations related to acidosis [8]. Thus, the larger anaerobic contribution of SPRs during early spurt of the all-out test [19, 20] induces a higher accumulation of metabolites [21] leading to a higher decrease in the $\dot{V}O_2$ during the last part of the exercise.

The purpose of this study was to investigate the impact of different training backgrounds (i.e., SPRs vs. ENDs) and metabolic perturbations on the $\dot{V}O_2$ responses during all-out and supramaximal constant-velocity running exercises. We hypothesized that the SPRs would have faster $\dot{V}O_2$ responses compared to the ENDs during all-out exercise. Conversely, the ENDs would have faster $\dot{V}O_2$ response during the constant-velocity exercise and a lower $\dot{V}O_2$ decrease during the last part of the all-out exercise compared to the SPRs. This cross-sectional study was a feasible way to assess the manner and degree to which each training background and the different pacing strategies affect $\dot{V}O_2$ responses, providing further information for the determinants of $\dot{V}O_2$ kinetics during supramaximal exercise.

Materials and Methods

Subjects

Seventeen men volunteered to participate in this study and provided written informed consent after a thorough explanation of the study protocol. This investigation was approved by the Santa Catarina State University Research Ethics Committee. This work was performed according to the Declaration of Helsinki. Subjects with different training status were deliberately targeted for this study, and were assigned to two groups. The first group was composed of eight endurance athletes (28.6 ± 4.2 yr, 176 ± 6 cm, 70.7 ± 8.1 kg), and the second group was composed of nine sprinters (19.6 ± 3.9 yr, 180 ± 7 cm, 78.5 ± 8.7 kg). The ENDs comprised 3 triathletes and 5 distance runners. The distance runners were specialists in 3000 m steeple chase events (1), 5–10 km (2) or marathon (2). The SPRs comprised 1 decathlete, 1 long jumper, 1 high jumper and 6 track sprinters. The track sprinters were specialists in 100 (4) or 400 m (2). All ENDs and SPRs participate in 10 km and 100 m events, respectively, during the year. The athletes competed at regional and/or national level events and trained for at least 1.5 years about 10 hours per week. Seasonal best performance time for SPRs on 100 m was 11.07 (range,

10.51–11.67 s) and for ENDS on 10 km was 35.34 min (range, 31.00–38.10 min). The personal best time corresponded to 86.7 ± 3.0 and $74.4 \pm 5.8\%$ of the current 100 m and 10 km world record, respectively.

Procedures

Three testing sessions were performed on a synthetic running track over a 2-week period. The first test was an incremental test to determine $\dot{V}O_{2\max}$ and maximal aerobic velocity (MAV). The following tests were a 1-min all-out test (1MT) and a constant-velocity running bout at 110%MAV, which were performed randomly. Prior to the 1MT and 110%MAV, subjects performed a pre-test warm-up consisting of 5-min running at approximately 65%MAV followed by three practice sprints of 5-10-m (interspersed with 20-s of jogging), and then, rested for 5-min. All sessions were performed at the same time of day (± 2 h) to minimize the effects of diurnal variations on the measured variables. Subjects trained during the experimental period, but were directed to arrive fully rested for the experimental sessions. Moreover, the subjects were asked to abstain from products that contained caffeine or alcohol on the test day.

Materials

During each test the respiratory gas exchange variables were collected, using a breath-by-breath portable gas analyzer (Cosmed K4^{b2}, Rome, Italy). The portable unit and the battery were fixed to the participant by a body harness. Calibration procedures were performed before each test, according to the manufacturer's recommendations.

Capillary blood samples were taken for the determination of amount of blood lactate accumulated (Δ BLC) in 1MT and 110%MAV. Δ BLC was calculated subtracting BLC immediately prior to the test from maximal BLC. While blood samples during incremental test and 110% MAV were collected at rest, immediately, 3, 5 and 7-min post tests, during 1MT blood samples were collected at rest, immediately prior to the test and for 60-min post-test (every 1-min from 0 to 10, every 2-min from 10 to 20 and every 5-min from 20 to 60 min). Arterialized capillary blood (25 μ L) was sampled by micropuncture at the earlobe, and then stored at eppendorf tubes containing 50 μ L of 1% NaF in a -30°C environment. Later, samples were analyzed by enzyme electrode technology (YSI 1500 SPORT, Yellow Springs, Ohio, USA). Before and after (3, 5 and 7-min) 1MT and 110%MAV, blood samples also were taken from a finger in heparinized capillary tube (150 μ L) to analyze blood pH. These blood samples were immediately capped, gently agitated, and then stored in an ice chest. Within 15-min of collection, all blood samples were analyzed at 37°C (GEM Premier 3000, Instrumentation Laboratory, Lexington, USA). Decrease in blood pH (Δ pH) was calculated as pH before the test minus the lowest pH after test.

Incremental test and supramaximal constant-velocity exercise

The Incremental test began at a velocity of $8.5 \text{ km}\cdot\text{h}^{-1}$ and was increased by $0.5 \text{ km}\cdot\text{h}^{-1}$ per minute until the participant terminated the test owing to volitional exhaustion. The subjects adjusted their running velocity to auditory signals at 20-m intervals, delimited by cones along the track. All subjects were encouraged to put forth their best effort. To determine the $\dot{V}O_{2\max}$, the $\dot{V}O_2$ was reduced to 15-s average values during the incremental test, and the highest 15-s $\dot{V}O_2$ value reached was considered the subject's $\dot{V}O_{2\max}$. MAV was calculated as the velocity of the last stage fully completed, plus, if necessary, the fraction of time spent multiplied by $0.5 \text{ km}\cdot\text{h}^{-1}$ in the stage at which exhaustion occurred.

The supramaximal constant-velocity exercise bout was performed twice at 110%MAV in the same day within a minimum interval of 1 h. During the tests, the subjects maintained a

constant-velocity according to the same auditory pacing procedure as described previously. The subjects performed the tests until volitional exhaustion or if they were stopped because they were more than 2-m late compared to the expected pace.

1-min all-out test

During 1MT the subjects were instructed to maintain their velocity as high as possible throughout the entire test. Verbal encouragement was provided as a motivation; however, the subjects were neither informed of the elapsed time nor of the remaining time to discourage pacing. The subjects ran on the inside lane, and performance variables were recorded by a digital video at a rate of 30 Hz (SONY DCR-SR68; Sony, Tokyo, Japan). The maximal velocity (V_{max}) was analysed by a camera, which was placed perpendicular to the direction of the cones placed every 5 m within the 20–60-m track, and was considered the highest mean velocity recorded between the cones. The mean velocity (V_{mean}) during the 1MT was calculated as the total distance covered (m) divided by 60s. The total distance covered was analysed using orange cones that were placed every 20 m along the track, and it was considered as the amount of cones overcome multiplied by 20 plus the distance exceeding the last cone, if necessary.

$\dot{V}O_2$ analysis

The breath-by-breath $\dot{V}O_2$ data from each test were initially examined to exclude occasional errant breath values, i.e. values lying more than three standard deviations outside the local mean (i.e. five-point rolling mean). To measure the $\dot{V}O_{2rest}$, the participants remained standing for 5-min prior to the test, and the $\dot{V}O_2$ of the last 2 min were averaged.

To characterize the overall $\dot{V}O_2$ kinetics during the 110%MAV, data were interpolated to give one value per second and time aligned. Data were then averaged across the two tests from 120 s prior to the onset of exercise to the end-point of the shorter of the two tests. Finally, a mono-exponential function was used to describe the $\dot{V}O_2$ response during 110%MAV:

$$\dot{V}O_2(t) = \dot{V}O_{2rest} + A(1 - e^{-\frac{(t-TD)}{\tau}}) \quad (1)$$

where $\dot{V}O_2(t)$ is $\dot{V}O_2$ at time t , $\dot{V}O_{2rest}$ is the pre-test $\dot{V}O_2$; A is the amplitude of the increase in $\dot{V}O_2$ above the pre-test value; TD is the delay between the start of the square wave and the onset of primary component, and τ is the time constant of the exponential response that comprises the primary component. The cardiodynamic phase or phase I was excluded from the analysis based on previous visual inspection. This visual inspection of the individual $\dot{V}O_2$ responses revealed that the first phase typically lasted less than 15 s. Hence we excluded just the first 15 s of data from the modelling of the primary response.

To characterize the $\dot{V}O_2$ response during the 1 MT, data were reduced to a 5-s stationary average. Moreover, for better comparing the groups we used $\dot{V}O_2$ relative to $\dot{V}O_{2max}$, and not the absolute $\dot{V}O_2$, because during supramaximal exercise the $\dot{V}O_2$ response drives $\dot{V}O_2$ to reach their maximum value (i.e. $\dot{V}O_{2max}$) [22]. Thus, comparing supramaximal $\dot{V}O_2$ response in subjects with different $\dot{V}O_2$ amplitude could be misleading with respect to interpreting possible training-induced on $\dot{V}O_2$ responses. Therefore, the comparisons using $\dot{V}O_2$ relative to $\dot{V}O_{2max}$ are more appropriate to analyze the $\dot{V}O_2$ response as it provides an indication of how fast is the changes in $\dot{V}O_2$ towards their predict asymptotic amplitude, that for supramaximal exercise is $\dot{V}O_{2max}$. In addition, the peak of $\dot{V}O_2$ ($\dot{V}O_{2peak}$) and the time to achieve the $\dot{V}O_{2peak}$ ($t\dot{V}O_{2peak}$) were calculated based on the highest $\dot{V}O_2$ value. The possible $\dot{V}O_2$ decrease was determined from the difference between the $\dot{V}O_2$ value at 30 s and the end-exercise $\dot{V}O_2$. Finally, the total O_2 consumed was determined as the time integral above the $\dot{V}O_{2rest}$

for the 5-s $\dot{V}O_2$ values. The O_2 consumed during the first and second half of the 1MT was also calculated.

Ventilatory variables

During the 1MT and 110%MAV, the peak value of minute ventilation, tidal volume, and breathing frequency (i.e., the $\dot{V}E_{peak}$, V_{Tpeak} , and BF_{peak} , respectively) were calculated based on highest 5-s average value during all the tests. Moreover, the possible declines in these parameters during the 1MT were determined from the difference between the value at 30 s and the end-exercise value.

Statistical analysis

The results are expressed as mean \pm SD. The Gaussian distribution of data was verified by the Kolmogorov–Smirnov test (with Lilliefors’ correction). In all cases, data were found to be acceptably normal. An unpaired t-test was used to assess the differences between groups for the parameters estimated from the $\dot{V}O_2$ responses and the metabolic parameters. A two-way analysis of variance (ANOVA) (group – time) with repeated measures on the time was used to assess the differences in the $\dot{V}O_2$ over time during 1 MT. When significant differences were observed, post hoc analyses were performed using Bonferroni corrections. The relationships between the $\dot{V}O_2$ parameters and the other variables obtained during the study were analysed merging all subjects into a single group and by using Pearson’s correlation coefficient (r). Statistical significance was set at $p < 0.05$.

Results

Incremental test and 1-Min all-out performance

[Table 1](#) presents mean \pm SD of the incremental test parameters and performance parameters during the 1MT. Compared to the SPRs, the ENDS had a higher MAV ($p < 0.001$) and $\dot{V}O_{2max}$ ($p < 0.001$), which corresponded to a difference of 17 and 14%, respectively. On the other hand, the SPRs had a faster V_{max} ($p < 0.001$) and V_{mean} ($p < 0.001$), which corresponded to a difference of 16 and 8% compared to the ENDS, respectively.

$\dot{V}O_2$ analysis and metabolic data

The main results of the $\dot{V}O_2$ kinetics and blood parameters during the 110%MAV test are presented in [Table 2](#). The $\dot{V}O_2$ kinetics during the 110%MAV was faster in the ENDS compared to SPRs ($p = 0.009$). Furthermore, the amplitude of the primary component was higher in the

Table 1. The mean \pm SD of the incremental test data and performance parameters during 1 MT for sprinters (SPRs) and endurance runners (ENDs).

	ENDs	SPRs
$\dot{V}O_{2max}$ (ml.kg ⁻¹ .min ⁻¹)	59.6 \pm 2.6*	51.5 \pm 2.9
MAV (m.s ⁻¹)	5.1 \pm 0.4*	4.6 \pm 0.2
V_{max} (m.s ⁻¹)	7.8 \pm 0.7*	9.2 \pm 0.6
V_{mean} (m.s ⁻¹)	6.6 \pm 0.3*	7.1 \pm 0.4

MAV, maximal aerobic velocity; $\dot{V}O_{2max}$, maximum oxygen uptake; V_{max} and V_{mean} , maximum and mean velocity during 1-min all-out.

* significant difference between groups ($p < 0.001$).

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Table 2. The $\dot{V}O_2$ kinetic parameters and blood parameters during the 110%MAV test for sprinters (SPRs) and endurance runners (ENDs).

	ENDs	SPRs	P value
$\dot{V}O_2$ rest (ml.kg ⁻¹ .min ⁻¹)	6.3 ± 0.8	6.7 ± 1.1	.42
A (ml.kg ⁻¹ .min ⁻¹)	49.0 ± 10.0*	40.2 ± 2.4	.042
TD (s)	6.8 ± 3.4	4.5 ± 5.1	.28
τ (s)	12.7 ± 3.0*	19.3 ± 5.6	.009
ΔBLC (mmol.l ⁻¹)	10.3 ± 3.5	10.4 ± 2.8	.92
ΔpH	-0.26 ± 0.07	-0.24 ± 0.09	.81

A, TD and τ are the amplitude, time delay and time constant estimated from $\dot{V}O_2$ kinetics. ΔBLC and ΔpH is the difference between pre test and peak exercise values of blood lactate concentration and pH, respectively.

*Significant difference between groups ($p < 0.05$).

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ENDs compared to SPRs ($p = 0.042$). Fig 1 shows the pulmonary $\dot{V}O_2$ response during the 110%MAV test.

The main results of the $\dot{V}O_2$ responses and blood parameters during the 1 MT are presented in Table 3. Compared to the ENDs, the SPRs had a significantly lower $\dot{V}O_{2peak}$, $t\dot{V}O_{2peak}$ and O_2 consumed during 1 MT ($p < 0.05$). In addition, when the O_2 consumed was divided into two parts, there was significant difference between the groups in the second half (44.5 ± 5.7 and 32.5 ± 4.3 ml.Kg⁻¹ for ENDs and SPR, respectively; $p < 0.001$), but not in the first half of the 1 MT (30.8 ± 3.6 and 28.0 ± 2.4 ml.Kg⁻¹ for ENDs and SPR, respectively; $p = 0.089$). There was a $\dot{V}O_2$ decrease for all SPRs and for only one endurance runner during 1 MT, which resulted in a significantly higher $\dot{V}O_2$ decrease in SPRs ($p < 0.001$).

Fig 2 shows the $\dot{V}O_2$ response during 1 MT. The ANOVA revealed a significant time and interaction effect ($p \leq 0.01$). The $\dot{V}O_2$ relative to the $\dot{V}O_{2max}$ was significantly higher in the first $\dot{V}O_2$ points (first and fourth time point, $p < 0.05$) and was significantly lower in the latest $\dot{V}O_2$ points (from the ninth until the last time point, $p < 0.05$) in SPRs compared to the ENDs. Furthermore, there was a statistical trend for a higher $\dot{V}O_2$ in the third time point in SPRs ($p = 0.09$). Finally, the sprinters was the only group in which the last $\dot{V}O_2$ time point was significantly lower than other $\dot{V}O_2$ time point (i.e., sixth, seventh and eighth time point, $p < 0.05$).

The SPRs had a higher ΔBLC and ΔpH during the 1MT ($p < 0.01$) compared to the ENDs. However, during the 110%MAV, no significant differences in the ΔBLC and ΔpH were observed.

Ventilatory parameters

The 1MT peak values of $\dot{V}E$, VT, and BF were 145 ± 10 and 139 ± 18 l.min⁻¹, 2.39 ± 0.32 and 2.38 ± 0.56 l.min⁻¹ and 76 ± 15 and 75 ± 13 breaths.min⁻¹ for the ENDs and SPRs, respectively, with no significant differences observed between groups ($p > 0.1$). During the 1MT, a decrease in $\dot{V}E$ was observed only in four SPRs and two ENDs. Furthermore, eight SPRs and seven ENDs had a decrease in BF, but only two SPRs had a decrease in VT.

Correlations

The time constant of the exponential response during the 110%MAV was significantly correlated with the $\dot{V}O_{2max}$ ($r = -0.58$) and MAV ($r = -0.65$). The $t\dot{V}O_{2peak}$ during the 1MT was correlated with the ΔBLC ($r = -0.74$), ΔpH ($r = 0.80$), V_{max} ($r = -0.61$) and V_{mean} ($r = -0.56$). Finally, the $\dot{V}O_2$ decrease and percentage of the $\dot{V}O_{2max}$ achieved during the 1MT was

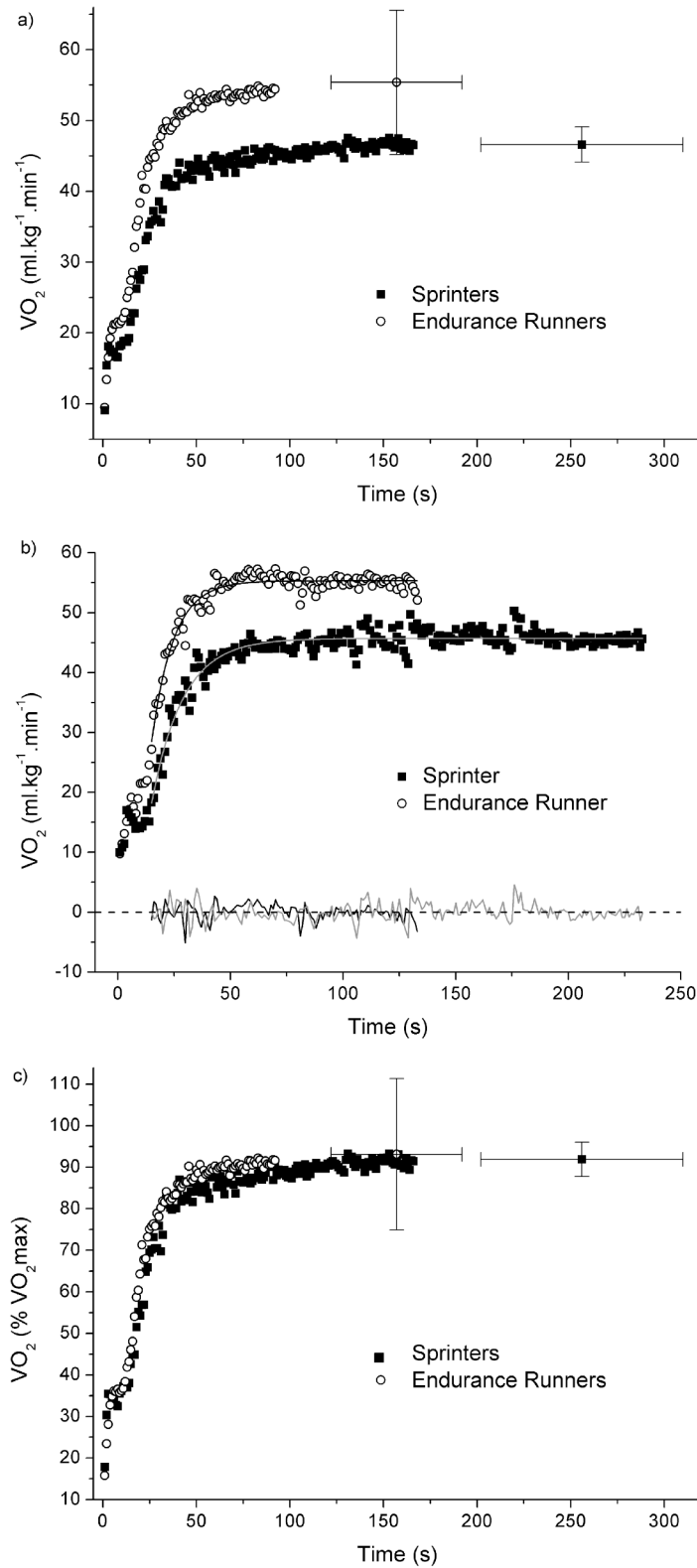


Fig 1. Pulmonary $\dot{V}O_2$ response during the 110% MAV test for group mean data (a,b) and for a representative subject in each group (c). $\dot{V}O_2$ was expressed in absolute and relative terms (% $\dot{V}O_{2\max}$) in Fig 1A and 1B, respectively. In Fig 1A and 1B, data were matched at the shortest time to exhaustion recorded in each group. Moreover, the mean \pm SD of the asymptote (i.e. amplitude + $\dot{V}O_2$ rest) and time to exhaustion are also shown. In Fig 1C, the exponential fits of the data and the residuals were also illustrated.

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Table 3. The $\dot{V}O_2$ responses and blood parameters during the 1-min all-out test for sprinters (SPRs) and endurance runners (ENDs).

	ENDs	SPRs	P Value
$\dot{V}O_2$ rest (ml.kg ⁻¹ .min ⁻¹)	6.4 ± 0.5	6.5 ± 0.7	.92
$\dot{V}O_{2peak}$ (ml.kg ⁻¹ .min ⁻¹)	52.6 ± 6.0*	42.4 ± 4.4	.002
$\dot{V}O_{2peak}$ (% $\dot{V}O_{2max}$)	88.2 ± 8.4	82.8 ± 5.9	.157
Total O ₂ consumed (ml.kg ⁻¹)	37.6 ± 4.0*	30.3 ± 3.3	.001
t $\dot{V}O_{2peak}$ (s)	40.6 ± 6.8*	28.8 ± 6.4	.002
$\dot{V}O_2$ decrease (ml.kg ⁻¹ .min ⁻¹)	-1.8 ± 2.3*	3.5 ± 2.3	< .000
ΔBLC (mmol.l ⁻¹)	12.4 ± 2.9*	19.2 ± 2.2	< .001
ΔpH	-0.29 ± 0.07*	-0.43 ± 0.06	.002

$\dot{V}O_{2peak}$ was determined as the 15-s rolling average; t $\dot{V}O_{2peak}$ is the time to achieve $\dot{V}O_{2peak}$; $\dot{V}O_2$ decrease is the difference between the $\dot{V}O_2$ value at 30 s and the end-exercise $\dot{V}O_2$; O₂ consumed was determined as the time integral above the $\dot{V}O_{2rest}$ for the 5-s $\dot{V}O_2$ values; ΔBLC and ΔpH is the difference between pre test and peak exercise values of blood lactate concentration and pH, respectively.

*Significant difference between groups ($p < 0.05$)

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correlated with the ΔpH ($r = -0.66$ and 0.82 , respectively), ΔBLC ($r = 0.74$ and -0.71 , respectively), V_{max} ($r = 0.69$ and -0.63) and V_{mean} ($r = 0.56$ and -0.59).

Discussion

The purpose of the present study was to compare the $\dot{V}O_2$ responses during all-out and supra-maximal constant-velocity running exercises in subjects with different training background. The important finding of this investigation was that, while the endurance athletes had a faster $\dot{V}O_2$ response during supramaximal constant-velocity running exercise, the sprinters had a faster $\dot{V}O_2$ response during all-out exercise. In addition, the sprinters presented a decrease in $\dot{V}O_2$ in the last part of the 1 MT.

Previous studies and the current one using constant-intensity exercise have reported faster $\dot{V}O_2$ responses in endurance athletes compared to nonathletic or other athletic populations and after endurance training [4, 5, 23]. Accordingly, some studies showed experimentally that the time constant of $\dot{V}O_2$ kinetics decreases with the increase of the mitochondrial content [24, 25].

During the 1MT, modeling the overall $\dot{V}O_2$ kinetics was not considered suitable, particularly because of the $\dot{V}O_2$ decrease and short time window. Therefore, it was analyzed only t $\dot{V}O_{2peak}$ and $\dot{V}O_2$ at each 5 s average time point. In contrast to constant running exercise, the comparison of such measures between the groups showed a faster $\dot{V}O_2$ response in SPRs. Indeed, for supramaximal exercises $\dot{V}O_2$ kinetics drives $\dot{V}O_2$ toward the overall energy requirement, but it is never reached since the increase in $\dot{V}O_2$ is constrained by $\dot{V}O_{2max}$. Therefore, for supramaximal intensities, the higher is the exercise intensity, the shorter is the time to achieve $\dot{V}O_{2max}$ when the exercise duration permits [26]. In addition, the postulated model of mitochondrial respiratory control suggests that the rate of adjustment of oxidative phosphorylation during the on-transient kinetics would be mainly linked by the rate of muscle ATP hydrolysis. Therefore, the level of cellular metabolic controllers is intimately linked to mitochondrial respiration through feedback control [13, 27, 28]. In this context, some studies have shown that the rate of phosphocreatine (PCr) breakdown in the active muscles is proportional to the changes per unit time in $\dot{V}O_2$ [13, 14]. This suggest that, in the present study, the higher speed of SPRs during all-out exercise could induce higher PCr breakdown and, consequently, have led to a faster $\dot{V}O_2$ response during all-out exercise. Therefore, considering the similar difference between groups in aerobic and anaerobic parameters, these putative factors show that despite the fact

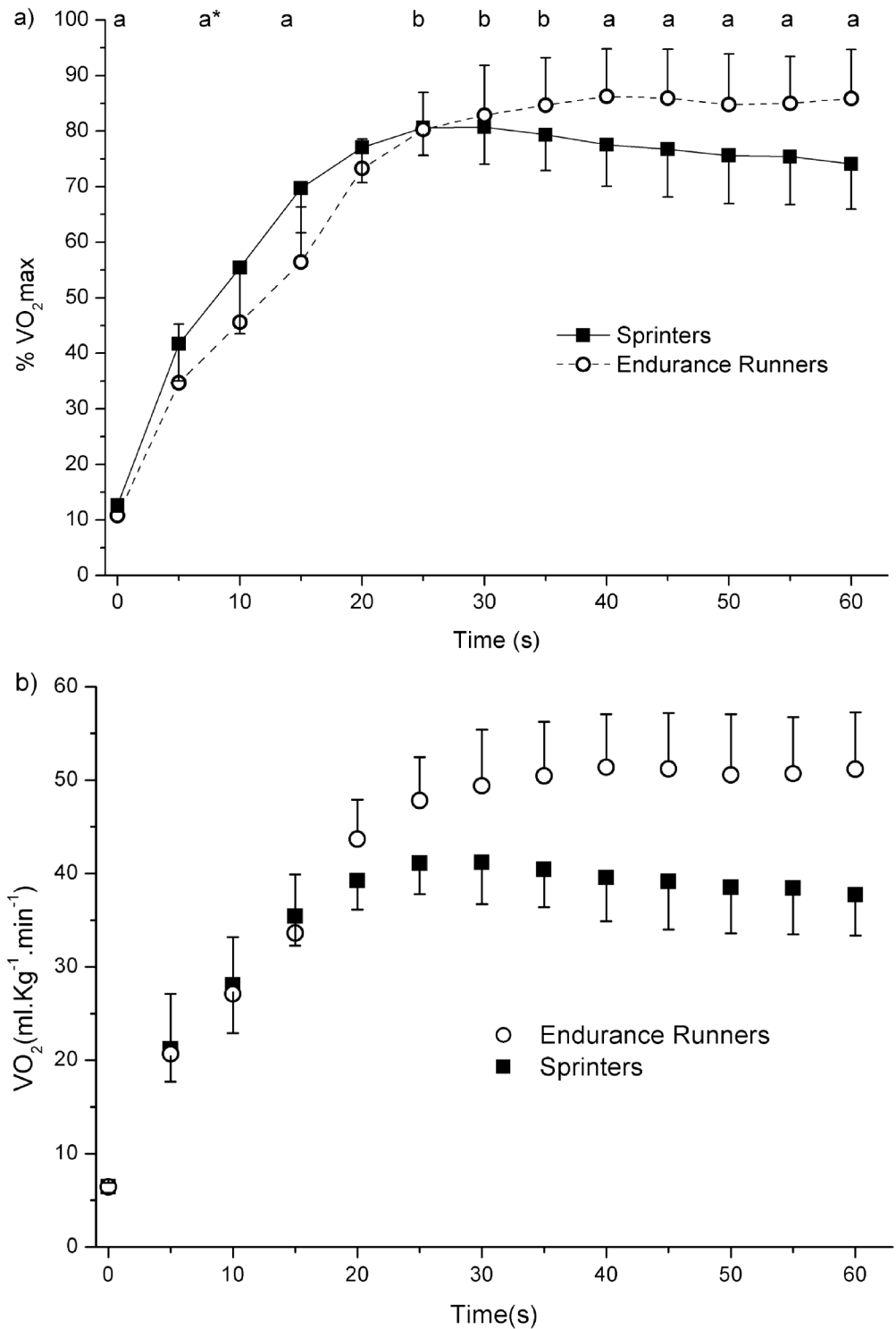


Fig 2. Time course of the $\dot{V}O_2$ during the 1 min all-out running test in sprinters and endurance runners. $\dot{V}O_2$ was expressed in relative (% $\dot{V}O_2$ max) and absolute terms in Fig 1A and 1B, respectively. Statistical analysis was only performed on relative terms. ^asignificant difference between groups ($p < 0.05$); ^{a*}statistical trend for a higher $\dot{V}O_2$ in sprinters ($p = 0.09$); ^b $\dot{V}O_2$ significantly higher than end-exercise $\dot{V}O_2$ in sprinters ($p < 0.05$).

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that capillary density and mitochondrial content affect the $\dot{V}O_2$ kinetics, it seems to be more dependent, at least for supramaximal intensities, on the change in the intermediate metabolite concentration per unit change in time [28]. In addition to these mechanisms, the correlation of the Δ BLC and Δ pH with $t\dot{V}O_{2peak}$ during the 1MT were consistent with a notion that lactic acidosis may increase muscle perfusion and O_2 delivery and thus speed-up the $\dot{V}O_2$ response [29, 30], though there are some evidences showing that the O_2 delivery to muscle does not seem to be a limiting factor for $\dot{V}O_2$ response [13].

SPRs achieved the $\dot{V}O_{2peak}$ faster during all-out running exercise, yet they obtained a lower O_2 consumed, representing <24% that consumed by the ENDs. Thus, the higher O_2 consumed during all-out exercise in ENDs seems to be linked to higher $\dot{V}O_2$ amplitude along the transition from rest to exercise as well as a meaningful $\dot{V}O_2$ decrease for SPRs during the latter half of the test. These results highlight that, although anaerobic training is highly important to sprint performance, the aerobic adaptation can assist for improving the long sprint performance. The lower difference between SPRs and ENDs for V_{mean} compared with V_{max} (from 16 to 8%) also corroborates with this premise. In this context, some studies have showed that a greater aerobic contribution has impacted positively during sprint tests [12, 31], as well as, sprint running performance seem to be determined by anaerobic parameters, in conjunction with $\dot{V}O_{2max}$ [32].

The $\dot{V}O_2$ decrease has previously been reported during long sprint running events [2, 8, 9]. In the present study, all SPRs had a negative value for the difference between the $\dot{V}O_2$ value at 30 s and the end-exercise $\dot{V}O_2$, indicating a $\dot{V}O_2$ decrease during the second half of the test. In contrast, the mean value of this difference was positive in ENDs. Some studies have indicated that a large glycolytic contribution may partially explain the $\dot{V}O_2$ decrease during short and intense running exercise [9, 18], and under *in vitro* conditions acidosis has been shown to inhibit oxidative phosphorylation in contracting muscles [33]. Therefore, our findings were expected since SPRs had higher metabolites derived from glycolytic metabolism during all-out exercise. The significant correlations of the Δ pH and Δ BLC with the $\dot{V}O_2$ decrease during all-out running exercise help support this premise. Additionally, it was suggested that a reduction of inspiratory muscle strength, which would be evidenced by a decrease in VT, can result in an $\dot{V}O_2$ decrease during exhaustive exercise [34]; however in the present study, only two SPRs had VT decline despite the fact that all SPRs had a $\dot{V}O_2$ decrease.

Burnley and Jones [35] and Di Prampero [10] have highlighted the importance of the $\dot{V}O_2$ response for supramaximal performance. Based on this, several studies have showed that pacing strategy may have marked impact on $\dot{V}O_2$ responses and, consequently, effects on exercise performance [9, 12, 36]. These studies and the current one showed that fast and/or all-out pacing strategy is necessary to reach a high relative $\dot{V}O_2$ in a short time, and to provide the best performance [9, 12, 36]. The present study also showed that there is a $\dot{V}O_2$ decrease in the last part the all-out test only for athletes with elevated anaerobic ATP turnover (i.e. sprinters). Although the inhibition of the oxidative phosphorylation by low value of pH seems to be harmful, successful performance on the long sprint running requires full use of the buffering capacity [37], and therefore critical final values of pH [38]. Since we are not able to evaluate the effect these responses on competitive races, further studies should be conducted, perhaps investigating the interaction between different fast pacing strategies and training status in a “real-life” running performance.

In conclusion, our findings showed that even though endurance runners had a higher aerobic power and O_2 consumed during all-out and supramaximal constant-velocity running exercise, the sprinters had a faster $\dot{V}O_2$ response when the maximum intensity was required. Therefore, the ability to speed-up the initial $\dot{V}O_2$ response during all-out supramaximal running exercise seems to be more dependent on the change of the intermediate metabolite

concentration per unit change in time than the aerobic background. In addition, our findings also showed that a high maximum intensity during all-out running exercise seems to lead to a higher decrease in the $\dot{V}O_2$ during the last part of the exercise, likely due to a higher accumulation of anaerobic metabolic by-products.

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Author Contributions

Conceived and designed the experiments: RAA FC. Performed the experiments: RAA FDL TT RSOC FC. Analyzed the data: RAA FDL TT RSOC FC. Contributed reagents/materials/analysis tools: FC. Wrote the paper: RAA FDL TT RSOC FC.

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